SUMMARY OF CALFED BAY-DELTA PROGRAM ANALYSIS STRATEGY FOR AGRICULTURAL ECONOMICS

Several assessment variables have been identified to provide ways of measuring and comparing the effects of CALFED Bay-Delta Program (CALFED) alternative components on agricultural economics. The key assessment variables include the number of irrigated acres, value of agricultural production, cost of production, and net farm income. These variables are quantitative measurements that result from the analysis and will be used to compare CALFED alternatives. Supporting variables that are needed to arrive at the assessment variables include agricultural water cost, agricultural surface-water delivery, agricultural groundwater pumping, water transfers, applied water quality, irrigation efficiency, and other costs of production. These may be supplied by other analytical analyses (e.g., water supply, water quality) or they may be generated as intermediate steps in the economics analysis. A number of other factors also affect the assessment variables including crop demands, weather, and cost of inputs such as fertilizer and labor; however, these have not been included in this discussion because CALFED components are unlikely to change their values.

Other variables of potential interest to stakeholders include financial investment (e.g., capital needs for improved water-use efficiency), fiscal impacts on local governments (tax and other revenues), land values, and effects of uncertainty of changes in water supply. These variables may be analyzed and discussed qualitatively but are not proposed to be part of the quantitative agricultural economics analysis. Regional employment and income are related to agricultural production but will be assessed under regional economics rather that under agricultural economics.

PROPOSED RELATIONSHIPS

The fundamental approach to estimating agricultural impacts assumes that decision makers (growers) respond to changing conditions in ways that attempt to keep their long-term profitability and productivity as high as possible. All of the proposed economic relationships reflect this assumption. The relationships below are organized by potential CALFED alternative components. For each action, the overall relationship between the action and response variables, as well as some of the key underlying economic relationships, is discussed.

WATER SUPPLY

Water supply (average quantity and reliability) may be affected directly through reoperation of existing facilities or addition of new facilities. It also may be affected indirectly as a result of changing rules and standards. The amount and reliability of surface-water supply to agriculture affects growers' choice of crops, irrigation system investment and management, and use of groundwater. These decisions are made to maximize expected long-run profit. If surface- water supply is reduced,

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growers will substitute other things for surface water to try to remain profitable. They may use more groundwater, grow crops that use less water, fallow some land, or invest in irrigation techniques that save water. It is likely that more than one of these strategies (or all of them) will be used. Similarly, if surface-water supply is increased, combinations of responses are likely (e.g., reduce groundwater pumping and reduce fallowing). The proposed relationships are the profit-maximizing levels of the intermediate and assessment variables as water supply changes. Underlying these are more fundamental economic relationships such as the demand and supply functions for different crops, the tradeoffs between irrigation efficiency and cost, and the relative costs of different water sources.

DEMAND MANAGEMENT AND DRAINAGE REQUIREMENTS

Demand management and drainage requirements can impose additional costs or provide financial incentives to growers and districts to change the way they operate. They may take the form of required actions (new regulations), subsidies (i.e., low-interest loans), or tax incentives; therefore, they either constrain agricultural production operations or change the relative costs of production. The proposed relationship would adjust cropping, water use, and irrigation decisions to remain as profitable as possible. Key underlying relationships are the supply functions for crops and the irrigation efficiency/cost tradeoffs.

LAND RETIREMENT

Land retirement may be part of a planned program to target certain lands or it may result as an economic response to changes in farming conditions like water supply, water cost, or new regulations. This potential program would target certain locations or total acres of land for retirement from irrigated production. The mix of crops retired will depend on the general location of the targeted land and on the demand and supply relationships for different crops. The overall relationships between land retirement and the different assessment variables would, again, be based on the long-term profitability criterion described above.

WATER QUALITY IMPROVEMENTS

Water quality improvements can increase crop yield, reduce the water needed to leach salts, and allow more salt-sensitive crops to grow. Impacts of improved water quality on crop production will be assessed using estimates of electrical conductivity (EC) or TDS. Improved quality can reduce the water applied for leaching of salts (reducing costs) and it can allow selection (or increase yields) of more salt-sensitive crops, which can increase revenue. The "Maas-Hoffman relationships" are proposed to estimate crop yield impacts, and standard leaching fraction calculations are proposed to estimate applied water for leaching.

WATER TRANSFERS

Water transfers from willing sellers to willing buyers can either increase or decrease agricultural deliveries to an area. Third-party impacts (e.g., changes in return flow or agricultural employment) may be positive or negative. CALFED actions may include facilitating water transfers, but no specific transfers would be assumed; therefore, the analysis of this action would provide general estimates of benefits (supply cost savings, additional revenue to sellers) and costs (third-party impacts). The proposed relationship assumes that water might be transferred if physical and regulatory conditions permit, and if the buyer's willingness to pay exceeds the seller's required compensation (plus transport losses and costs, transaction costs, etc.).

WATER CHARGES

Some portion of the costs of implementing CALFED actions may be recovered through surcharges on water rates. If so, these increases in water charges might affect agricultural decisions. For example, some crops may be less able to support higher water costs than others. As in reduced water supply, higher surface-water cost may affect crop mix, irrigation efficiency, and groundwater use.

PROPOSED APPROACH

CALFED actions will potentially change the conditions under which growers operate, and the impact analysis must estimate how growers are most likely to react to those changes. There are two basic approaches to estimating growers' reactions: 1) use information observed from past changes to predict the response to future changes, and 2) create a mechanistic model that estimates changes based on observations and assumptions about growers' behavior. CALFED staff proposes to use an analytical approach that combines these two ideas. An example of this approach is based on an analytical tool developed at the California Department of Water Resources that was extensively revised and updated for use in assessing the impacts of the Central Valley Project Improvement Act and is described below.

The Central Valley Production Model (CVPM) is a regional agricultural production model covering the region extending from Redding to the Tehachapi Mountains. The model includes 26 crop categories and up to 22 subregions. It was specifically designed to serve as a tool for planning and assessing regional impacts on irrigated agriculture resulting from changes in market or resource conditions. CVPM estimates responses or changes in the agricultural sector by assuming that growers attempt to maximize long-run profitability subject to conditions and constraints imposed by market conditions, supply and cost of resources (including water), and government programs and regulations. CVPM is designed to estimate changes in regional irrigated acres, water use, irrigation efficiency, production costs, and gross and net revenue resulting from changes in water supply or cost, water transfers, and demand management programs (including land retirement and conservation standards). CVPM includes an extensive database including irrigated acres, water supply by source, crop prices

and yields, production costs, irrigation efficiency and cost. It also incorporates available information on crop price elasticities (flexibilities) and acreage response elasticities. This information is used to calibrate the model.

Assessment Variable	Supporting Variable		CALFED Action Component*

III. Socioeconomic Environment

B. Agricultural Economics

Assessment Variable	Supporting Variable		CALFED Action Component*
1. Agricultural net income	Crop revenue	Acres in agricultural production	Demand management, land retirement
	Cost of production		FEEDBACK
	Water transfers		Facilitate water transfers
2. Value of production	Acres in production	Land quality	FIXED
	Crop prices	Crop demand	FIXED
	Crop choices	Crop revenue and production costs	FIXED
		Land quality and quantity	Land retirement
3. Cost of production	Cost of surface water used	Surface-water supply and distribution	Demand management
		Surface-water quality	FEEDBACK
	Groundwater costs	Groundwater elevation	FEEDBACK
		Groundwater quality	FIXED
	Irrigation efficiency and costs	Irrigation system investment	Water conservation
		Cost of water	Financing options
	Production costs		FIXED
	Acres in agricultural production		Demand management, land retirement

* FIXED = relationship is assumed to not change.
INPUT = monthly hydrologic or meteorologic conditions.
FEEDBACK = relationship is addressed elsewhere in table.
FLOWS = water management control.
IFIM = Instream Flow Incremental Methodology
BMP = Best Management Practices

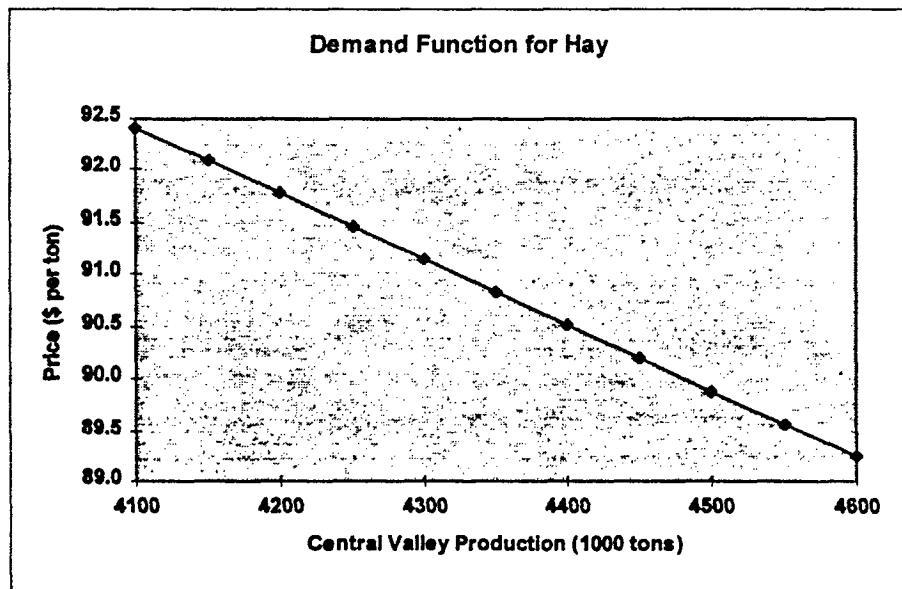**Resource Category:**   Agricultural Economics

Relationship: Crop Price vs. Crop Production

Description: The economic demand for a particular crop is a description of how much buyers are willing to pay for different total amounts sold. All else equal, the market price and quantity bought will generally move in opposite directions. Thus, prices rise when there is a crop failure or shortage. The relative rate at which price and quantity change is measured either as an elasticity or a price flexibility.

Assumptions: Price elasticities or flexibilities from existing empirical studies can be adapted to reflect the price effect of a given change in production. A linear relationship between price and production is an adequate representation of demand.

Basis: (1) Literature review of existing studies.

Reference: (1) Numerous crop demand and price flexibility studies reviewed for CVPIA Programmatic EIS. (2) Central Valley Production Model: Supporting Documentation and Data. USBR. November, 1994.

Demand Function for Hay

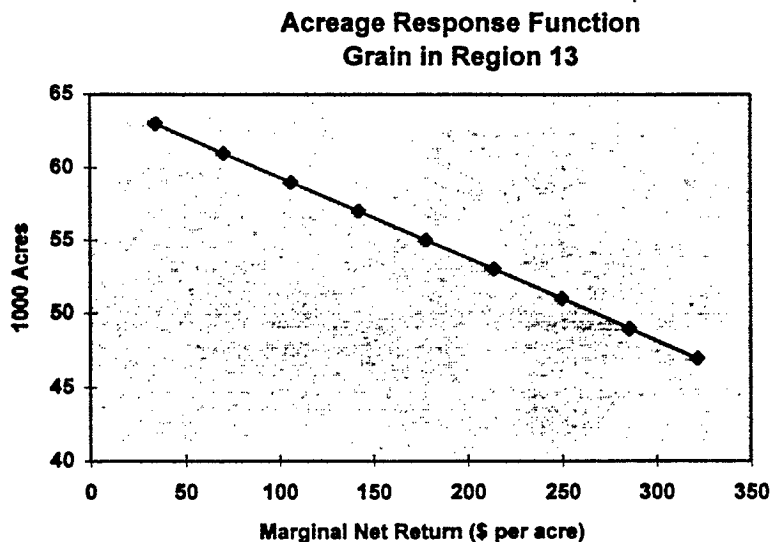| Resource Category:	Agricultural Economics
Relationship:	Declining Marginal Returns to Crop Production

Description: Economic analysis typically assumes that producers in a region will use the most productive land first, followed by less productive land as total acreage expands. Productivity differences can reflect differences in crop yield, crop quality, or per unit cost of production. Therefore as acreage of a given crop expands (all else equal), total net returns increase but at a declining rate. Marginal returns decline as acreage increases. The rate at which marginal returns decline is usually based on empirical data or, absent appropriate data, on reasonable assumptions.

Assumptions: Producers use land in order of declining productivity. A linear relationship between unit net returns and acreage produced can be approximated based on observed yield or cost variation in a region or on estimated acreage response elasticities.

Basis: (1) Literature review of existing studies and estimates using database of Central Valley Production Model

Reference: (1) Existing studies reviewed for CVPIA Programmatic EIS. (3) Central Valley Production Model: Supporting Documentation and Data. USBR. November, 1994.

Acreage Response Function
Grain in Region 13

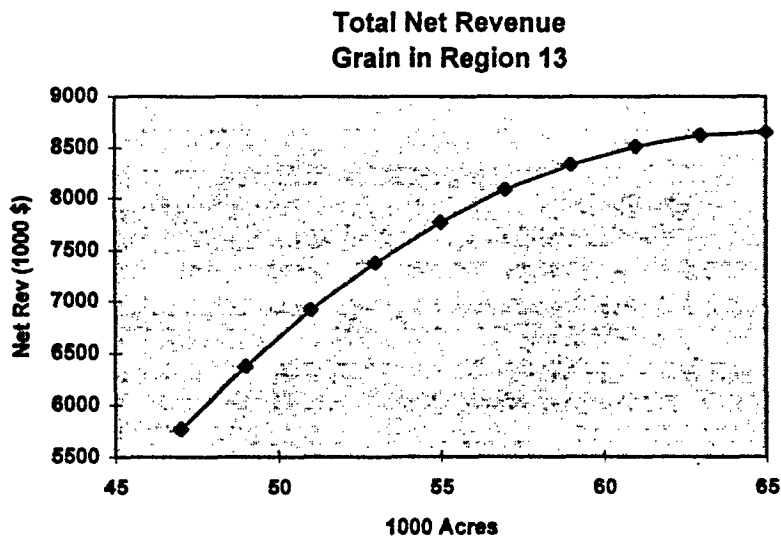**Resource Category:** Agricultural Economics

Relationship: Net Revenue of a Crop vs. Level of Production

Description: For a given crop and set of growing conditions, the net revenue per unit (acre) produced declines as production increases.

Assumptions: Growers in general use the best available land to grow a crop. If resources such as water supply are constrained, the best land will be used. As more resources (water) become available, less suitable land will be brought into production. Land quality can affect the crop yields and/ or the unit costs of production.

Basis: (1) Average unit costs, yields, and net revenues can differ substantially from the corresponding marginal values. (2) Quadratic cost and/or revenue functions can be used to estimate these relationships.

Reference: (1) Howitt, R. Positive Mathematical Programming. American Journal of Agricultural Economics. 1995. (2) Central Valley Production Model: Supporting Documentation and Data. USBR. November, 1994.

Total Net Revenue
Grain in Region 13

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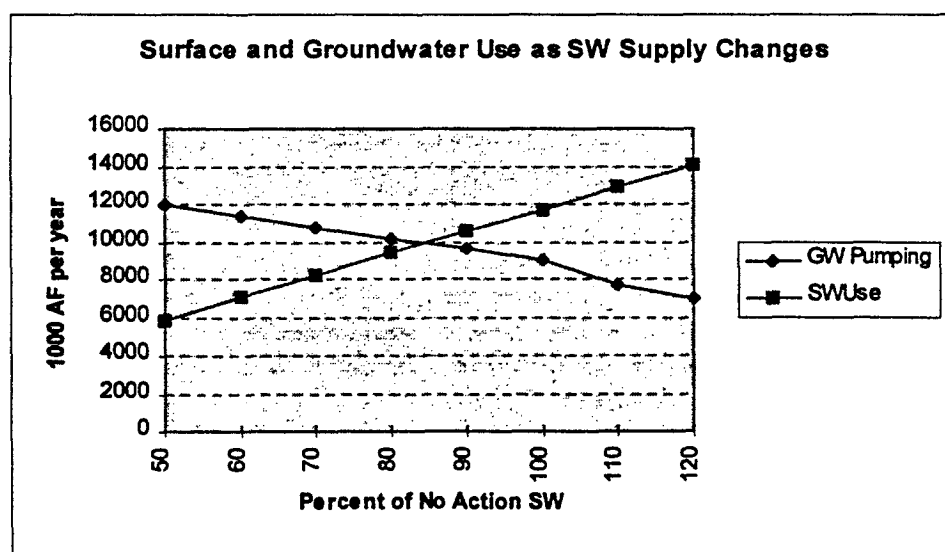**Resource Category:** Agricultural Economics

Relationship: Irrigation Water Use vs. Water Cost and Availability

Description: The demand for a particular source of irrigation water (e.g. CVP water or groundwater) depends on the underlying market demand for the crops grown, the profitability of irrigated production, the cost of the water, and the availability and cost of substitute sources.

Assumptions: A regional optimization approach can represent the interaction of the factors listed above, and can estimate how changes may affect the use of irrigation water. Cost of groundwater depends on the pumping lift, which depends on the net rate of groundwater extraction/recharge. Information from or iteration with a groundwater model is recommended.

Basis: Central Valley Production Model (CVPM). Water use by source is jointly dependent on other results of CVPM. Water use, irrigated acres, irrigation efficiency, and other variables are calculated simultaneously within CVPM.

Reference: Central Valley Production Model: Supporting Documentation and Data. USBR. November, 1994.

Surface and Groundwater Use as SW Supply Changes

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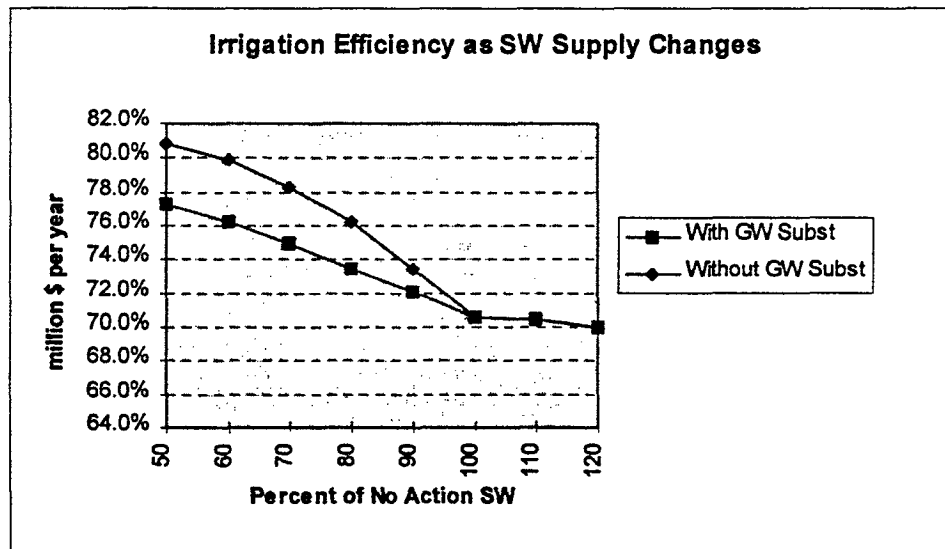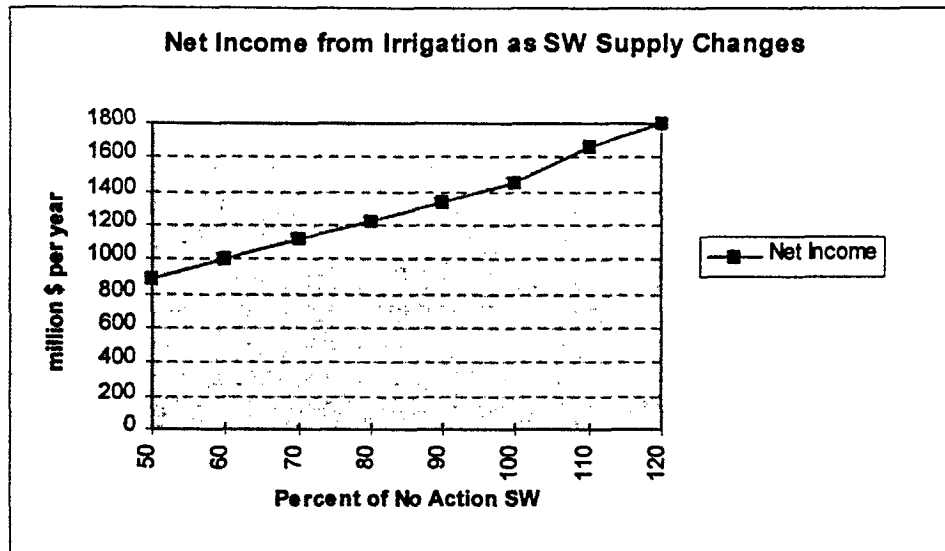**Resource Category:**   Agricultural Economics

Relationship: Irrigated Acres, Irrigation Efficiency, Value of Production, Net Revenue from Irrigation vs. Water Delivery, Water Cost, Conservation Requirements, etc.
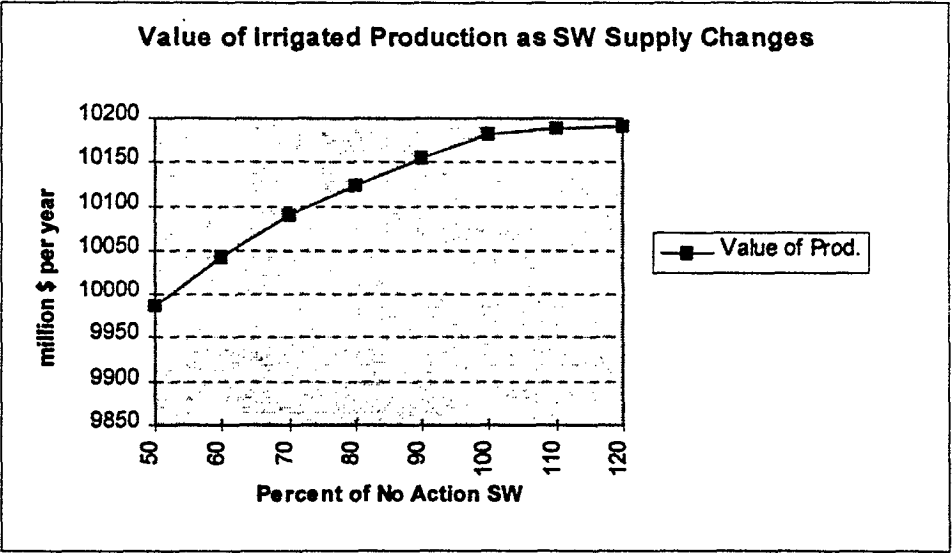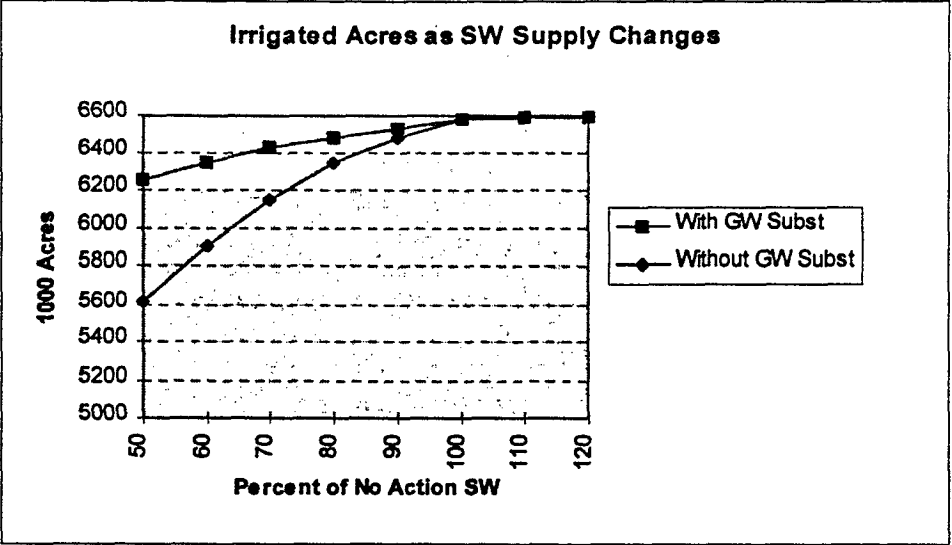
Description: Changes in irrigated acres, irrigation efficiency, value of production, and net revenue are the joint, or simultaneous, responses made by farm decision-makers when economic or resource conditions change. The mixture of responses can be forecast based on statistical estimates of past behavior, or it can be based on models that try to capture the underlying mechanism of agricultural decision-making.

Assumptions: For purposes of describing the relationships, a mechanistic optimization model is used. Central Valley Production Model (CVPM) incorporates more of the potential control variables, response variables, and key relationships than any other known model. The attached graphs result from sensitivity analysis of CVPM, with surface water delivery varied by 10 percent increments.

Basis: Long-run profit maximization is the dominant assumption used in economic policy analysis of agriculture and many other sectors.

Reference: (1) See, for example, Dinar, and Zilberman. Economics and Management of Water and Drainage in Agriculture. 1991. (2) Central Valley Production Model: Supporting Documentation and Data. USBR. November, 1994.

Net Income from Irrigation as SW Supply Changes

Irrigation Efficiency as SW Supply Changes

Irrigated Acres as SW Supply Changes

Value of Irrigated Production as SW Supply Changes

**Resource Category:**   Agricultural Economics

Relationship: Irrigation Efficiency vs. Cost of Irrigation System

Description: For a given crop and set of growing conditions, a tradeoff exists between the efficiency of water application (measured as ETAW/AW) and the cost of applying irrigation water. Costs increase because of investment in hardware to apply water more precisely and greater levels of management and information.

Assumptions: Higher cost results in greater efficiency and lower water use, but at a diminishing rate of return. The relationship between water use and irrigation system cost is generally a convex function: higher costs achieve declining incremental reductions in water use. A further implication is that the cost of achieving an efficiency target increases at an increasing rate (e.g., the cost of improving efficiency from 60% up to 65% is lower than to improve it from 65% to 70%).

Basis: (1) Both water and irrigation systems are costly, so growers attempt to minimize costs by trading off the two costs. When attempting to save water, growers will choose the cheaper system modifications first. (2) A convex functional form called the Constant Elasticity of Substitution (or CES) function provides a flexible and reasonable representation of the tradeoff.

Reference: (1) On-Farm Irrigation Systems and Management. Technical Memorandum. San Luis Unit Drainage Program. USBR. January, 1991. (2) Irrigation Cost and Performance. Technical Memorandum. CVPIA Programmatic EIS. USBR. June, 1994. (3) Central Valley Production Model: Supporting Documentation and Data. USBR. November, 1994.

Annual Irrigation System Cost vs. Relative Water Use
Row Crop Irrigation Technologies
Sacramento Valley
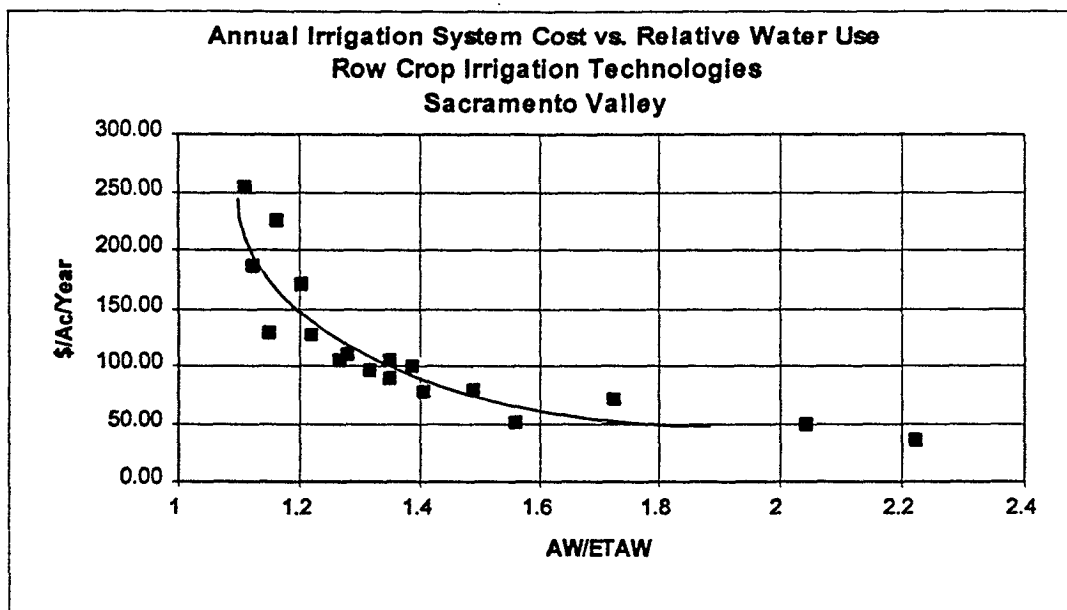
Estimated Isoquant:

$a \cdot [b \cdot (AW/ETAW)^p + (1-b) \cdot (ICcost)^p]^{1/p} = 1$

CES Parameter Estimates

p =	-0.702	F statistic 2637.643
b =	0.133	
a =	0.062	Elasticity of
		Substit. = 0.587